JPRS: 4951

6 September 1961

SELECTIONS ON HYDROGEOLOGY AND ENGINEERING GEOLOGY

- COMMUNIST CHINA -

Distributed by:

OFFICE OF TECHNICAL SERVICES
U. S. DEPARTMENT OF COMMERCE
WASHINGTON 25, D. C.

U. S. JOINT PUBLICATIONS RESEARCH SERVICE
1636 CONNECTICUT AVE., N. W.
WASHINGTON 25, D. C.

JPRS: 4951

CSO: 1599-S/a-e

SELECTIONS ON HYDROGEOLOGY AND ENGINEERING GEOLOGY

- Communist China -

/The following are translations of selected articles from Shui-wen Ti-chih Kung-ch'eng Ti-chih, No 1, Peiping, 12 January 1959./

TABLE OF CONTENTS | Page

THE ORIGIN OF BRECCIATED LIMESTONE OF THE CHIA-LING RIVER SYSTEM IN THE MIDDLE AND UPPER TRIASSIC PERIOD IN SOUTHEASTERN SZECHUAN

/Following is the translation of an article by Ch'ien Hsueh-p'u (6929 1331 3302), in Shui-wen Ti-chih Kung-ch'eng Ti-chih, No. 1, 12 January 1959, pp. 17-21./

I. Introduction

The limestone of the Middle and Upper Triassic Period in the Chia-ling River system in southeastern Szechuan is commonly mixed with a thick layer of brecciated limestone. The study of the origin of brecciated limestone has a great significance in the formulation of ancient and historical geography, petroleum resources, hot springs and the hydro-geological conditions of mineral mountains and water facilitie

In the past only a few articles have been published concerning the origin of brecciated limestone in the Chia-ling river system in southeastern Szechuan. We consider these brecciated limestones to be typical products of gypsum.

II. Distribution and characteristics of brecciated limestone.

1. Limestone mixed with brecciated limestone in the Chia-ling river system is distributed in southeast Szechuan, i.e., it appears in arc form at the inclined axial part of East Szechuan and at the south edge of Szechuan basin. The distribution area extends from Shih-chu, Chung-hsien and the Feng-tu districts in the east to T'ung-chieh-tzu in the west, and from the Ch'u-hsien, Ta-hsien and Liang-shan districts in the north to the basin's edge at the intersection of the Szechuan and Kweichow boundary in the south (references 2-6, 9, 11, 12). The area is about 450 km wide and 350 km long (Fig.

2. Limestone of the Chia-ling River system generally has a 600-700 m thickness, which can be divided into five layers according to their characteristics. The 5th layer is

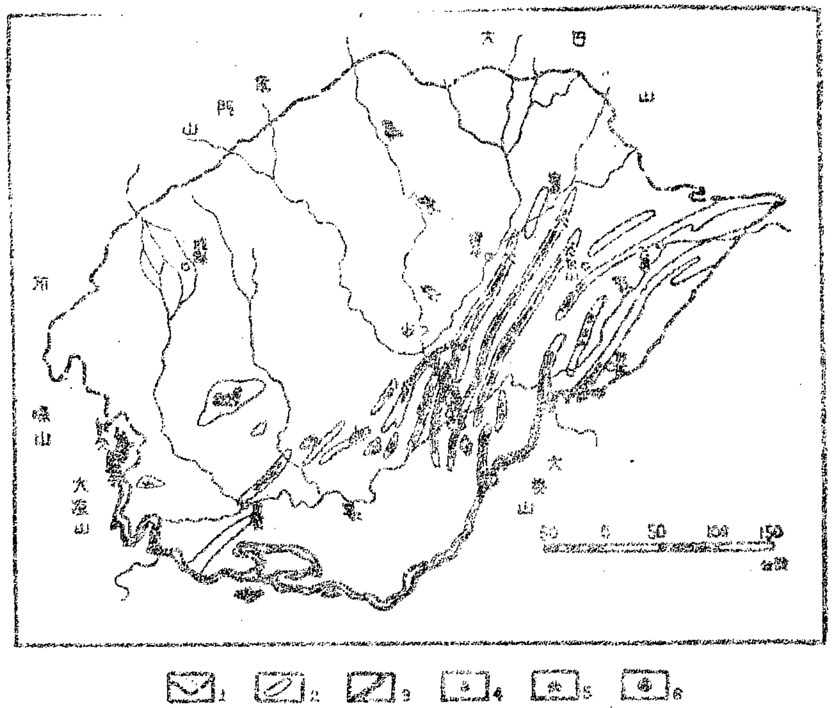


Fig. 1
Distribution map of brecciated limestone of the Chia-ling River system in the middle and upper Triassic Period in southeastern Szechuan.

1. The edge of the Szechuan basin.
2. Inclined and hollowed structure in the basin.
3. Area where limestone appears in brecciated limestone of the Chia-ling River system.
4. Hot springs.
5. Gypsum mineral production district in the Chia-ling River system.
6. Column-shaped section map of the ground layer (Fig. 2).

Locations: 1. T'ao-tzu-tang. 2. Shih-yu-kou. 3. South hot spring. 4. Kuan-yin-hsia. 5. Li-pi-hsia. 6. Huang-kua-shan. 7. Kua-teng-shan. 8. Wu-wei.

covered by a coal system of the Jurassic Period forming a false combination. The 5th layer sometimes is reduced to a thin layer or even to non-existence. According to Lo Chih-li (0925 1807 4539) the layers 1-3, which belong to the Middle Triassic Period, are called the "Chia-ling River System" (in a narrow sense) and the 4th layer, which belongs to the Upper Triassic Period, is called the "Lei-k'ou-p'o System" (reference 13).

The brecciated limestone is mixed between the middle part of the Middle Triassic Period and the bottom part of the Upper Triassic Period. That which is found in the latter is especially well developed.

3. Szechuan basin is a more stable portion of Yang-tzu-ti-t'ai; limestone of the middle and upper Triassic Period in the Chia-ling River, which belongs to a continental platform type of shallow phase, has bio-chemical sediments and varies slightly in an east-west direction. Its characteristics can be compared over an extensive area. Based on the extensive deep well drilling survey for petroleum in the Szechuan basin, Lo Chih-li pointed out firstly that the breccia layer of the ground surface is equivalent to the hard gypsum layer at the bottom of the well (reference 12).

We compiled a column-shaped comparing figure for rock layers in the district. From the figure the relative conditions of the brecciated limestone and hard gypsum layers can be clearly seen, based on the ground survey and data of well bottoms from various petroleum drilling districts (Fig. 2).

(From the left)

1. Wu-wei
2. Kua-teng-shan
3. Huang-kua-shan
4. Li-pi-hsia
5. Kuan-yin-hsia
6. S. hot spring
7. Shih-yu-kou
8. T'ao-tzu-tang

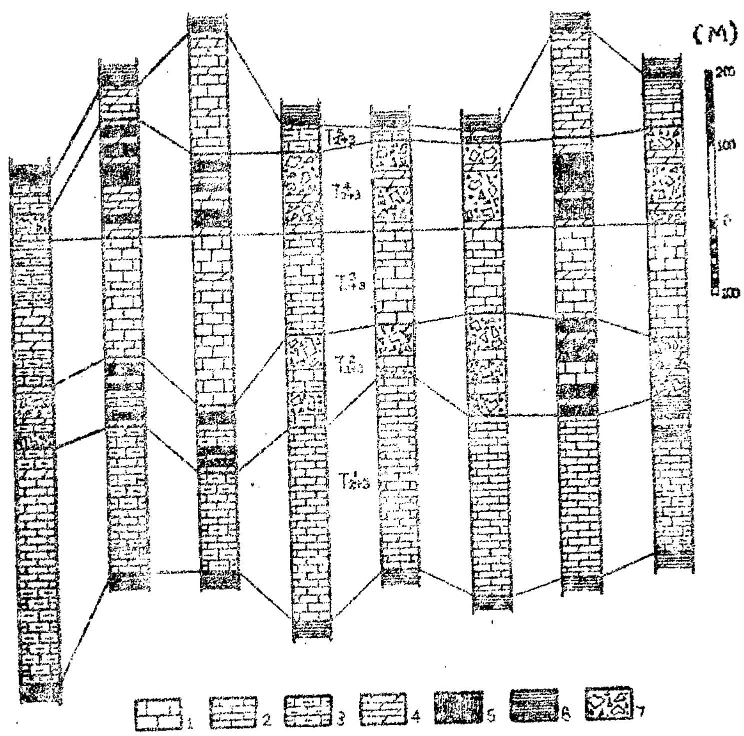


Fig. 2. Column-shaped comparing map of the ground surface and well bottoms of the Chia-ling River limestone layer.

1. Thick layer limestone 2. Thin layer limestone 3. Clayey limestone 4. Dolomite limestone and dolomite 5. Hard gypsum layer 6. Shale 7. Brecciated limestone.

4. It was discovered that the bottoms of the deep wells in Shih-yu-kou survey district are hard gypsum (waterless gypsum) blue-grey in color (Photo 1) and, as shown by microscopic examination, radial fabric in structure and 20-30 m thick (Photo 2). The hard gypsum layer has great plasticity and little cleavage. Therefore, from the viewpoint of reserve structure of oil, gas and water, it is a relatively mixed layer.

5. The brecciated limestone of the second layer of the Chia-ling River system is commonly 80-120 m thick and is frequently mixed with thin layers of schist, shale, or limestone.

The breccia does not clearly show the layer; it is composed of shale or limestone similar to nearby stones. It has prismatic angles of different sizes (Photo 3), usually 5-20 cm, its longest dimension reaching 1.5 m. The colloid between the breccia is composed of coarsely broken stones and clay (Photo 4).

Part of the breccia contains a thin layer of calcium shale; it has a gentle-folding where the shale breaks.

6. From microscopic examination no mineral gypsum was discovered in the ground brecciated limestone; only one gypsum layer, 1 m thick of coarse crystal white-grey in color, was discovered in the brecciated limestone 125 meters deep at drilling hole #33 in the south bank of Mao-chi-ya (Photo 5). It was determined through a microscope that this gypsum was ordinary gypsum (gypsum containing water) with integral crystalloid (Photo 6).

On the ground at the edges of the brecciated limestone distribution area, gypsum usually appears forming a gypsum mineral bed (Fig. 1). For instance, gypsum was produced on the top of the Chia-ling River's limestone at Ta-wei-hsien, about 30 km west of western T'ung-chieh-tzu (reference 12); gypsum was produced also in the north part of Ch'u-hsien, Liang-shan and Ta-hsien districts (references 4 and 8). The gypsum of the Chia-ling River system, consisting of two layers, is mixed between brecciated limestone layers. One layer lies near its top; the other, in the middle. Both are water containing gypsum (reference 7).

III. Some assumptions on the origin of brecciated limestone.

1. When Mr. A. Heim did a geological survey near Chung-ch'ing in 1913, he discovered the brecciated limestone. In his paper he assumed that the brecciated limestone might exist naturally; it is probably a breccia formed by the movement or sliding of sediments on an inclined slope near the sea bottom, becoming a colloid (reference 1).

2. During the geological survey made by P'an Chung-hsiang (3382 6988 4382) and P'eng Kuo-ch'ing (1756 0948 1987)

in 1939 at Ch'i-chiang district of south Szechuan, brecciated limestone was similarly discovered. In their paper they considered these brecciated limestone possibly to be a kind of intermittent product of sediments (reference 2).

3. In recent years extensive deep well drilling surveys were conducted in Szechuan basin to find petroleum resources and natural gas. Many drilling data proved that no brecciated limestone was distributed in the deep underground, the relative layers of which are thick layers of hard gypsum, schist and limestone (ref. 12 and 13). This can hardly be explained by the theory of sea-bottom sliding or the theory of intermittent sediments.

Following Lo Chih-li's relative comparison between ground brecciated limestone and the position of the hard gypsum layer, he considered the ground brecciated limestone to be a result of hydrolysis, a dissolving and crystalizing action of the sandwiched gypsum. Hard gypsum absorbs water, becoming water-containing gypsum, its volume increasing 67%. This breaks the layers above and below to form the brecciated limestone, a product of crystallized action. In his report Lo Chih-li brought to attention the similarity of this brecciated limestone to Russian crystal breccia, which resulted from gypsum crystallizing in the "Niao-la-erh-a-k'o-ch'iu-pin-szu-k'o" district (ref. 12).

IV. New comments on the formation of brecciated limestone.

Lo Chih-li considered the brecciated limestone to be formed later, pointing out also that this breccia was related to the hard gypsum layer. The assumption is evidently a remarkable improvement in the knowledge of breccia limestone formations. However, we consider the Crystallizing Theory to over-stress the volume swelling action when hard gypsum becomes water containing gypsum and to neglect the collapsing action after the gypsum has dissolved. Actually, the Russian breccia is composed of shale, sandstone and clayey stone fragments several mm to 2 cm in size; its colloid consists of clay and gypsum (ref. 14); it is different from the breccia of Szechuan in both structure and composition.

Based on data from references, interlaced gypsum commonly appears at the top of limestone in Shansi Province; for instance, T'ai-yuan Hsi-shan has several layers of water containing gypsum with thicknesses reaching 1-5 m. The brecciated limestone is sandwiched between small, gypsum layers, its thickness usually being less than 1 m (ref. 10). We consider these breccia, as far as its formation as a crystal breccia is concerned, to be similar to those of the "Niao-la-erh-a-k'o-ch'iu-pin-szu-k'o" district. The differences between the formation of brecciated limestone of Shansi and that of Szechuan might be because the gypsum layer

in Shansi Province is thinner.

During the formation of brecciated limestone in Szechuan, we consider the existence of "K'o-szu-t'e" collapsing. This is illustrated by the following facts:

1. Through microscopic examination no mineral gypsum was found in the ground brecciated limestone, while the thickness of the hard gypsum layer in the well's bottom can reach 20-30 m. Gypsum is easily dissolved; after dissolvement, the phenomenon of collapse near the ground surface can readily be seen.

2. In Ch'uan-chi coal mine at Ho-ch'uan-hsien it was frequently discovered that the broken coal layer had been replaced by a phenomenon of irregular "sand pier" (Fig. 3).

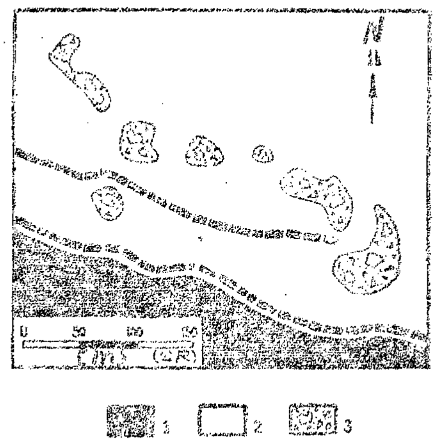


Fig. 3. Distribution Map of Ta-yang-sa-teng at East of Chien-chi Coal Mine

1. Coal Bed of Jurassic Period
2. Explorite Portion
3. Sandy Hills

The sand pier, which is composed of sandstone, shale breccia and coal fragments, has a longest dimension of several meters to 60 m. The largest breccia exceeds 1 m, while the smallest one is only a few mm. They are complicatedly mixed without distinct layers; the sand pier generally passes up and down through several coal layers. The small scale broken layer frequently can be found in nearby locations (ref. 17).

The coal layer of the Ch'uan-chi coal mine was taken directly from the upper covering of the Chia-ling River limestone where the layer is sloping gently with an angle of only 20 -25 . Therefore, we consider the sand pier to be a collapsing phenomenon.

3. Based on the recorded data from Chung-liang-shan Nan-p'ing-t'ung of Chung-ch'ing, sandstone and shale breccia were found in the brecciated limestone at the top of the Chia-ling River system. This phenomenon can be explained

only if sand and shale breccia are derived from the covering of coal systems of the Jurassic Period and are results of "K'o-szu-t'e" collapsing.

In short, we considered the breccia limestone of the Chia-ling River system in southeastern Szechuan to be a gypsum product and the swelling action of hard gypsum by hydrolysis and crystallizing during the formation of breccia to be of secondary importance. The breccia was distributed in the ground layer and the layer where it was not very deep. Based on the drilling results at Mao-erh-hsia, the distributed depth was estimated to be 200-400 m (Fig. 4).

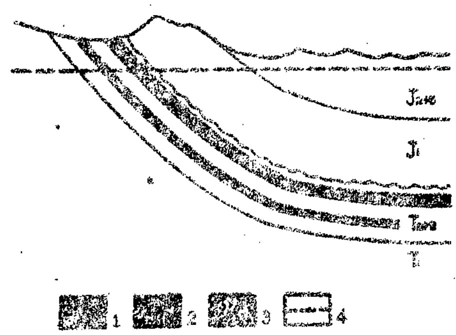


Fig. 4. Cross-section Map Showing Vertical Distribution of brecciated Limestone of Chia-ling River System in Southeastern Szechuan

1. Hard Gypsum
2. Aquifer Gypsum
3. Brecciated Limestone
4. Cocal Eroded Surface

In (Samarskaya River Bend)Russia a thick dolomitized limestone layer of the Stone-Coal Period was distributed. A gypsum layer was sandwiched between the dolomite limestone, a total thickness of 200 m. This kind of gypsum layer apparently existed in the west of the "Sa-ma-la-ho-ch'u" district, while in the east it was replaced by the brecciated limestone.

Brecciated limestone has been hotly debated. Some geologists believe that the brecciated limestone resulted from collapsing sediments and colloids after "K'o-szu-t'e" dissolving. This assumption was later proved by a geological survey of the "Ku-pi-hsu-fu" water power station at "Sa-ma-la-ho-ch'u" (ref. 15 and 16).

We consider the brecciated limestone in southeastern Szechuan of the Middle and Upper Triassic Period to be similar to the brecciated limestone of the Stone-Coal Period at "Sa-ma-la-ho-ch'u", Russia, as far as its formation is concerned.

V. The geological and hydrogeological significance of studying the formation of brecciated limestones.

1. Since we consider the breccia to be a result of collapsing, it can not be a product of sliding near the sea bottom, but it can be a product of structural reaction of the hard gypsum layer. Also, it can not geographically-historically represent a sedimented intermission.

2. Based on the observation of the district in parts, structurally the breccia that resulted from collapsing was freely mixed up with the breccia of the broken layer (ref. 3).

3. On ground surface, the brecciated limestones have high void ratio (based on test result: The void ration of limestone at Chia-ling River is 2-4%, and of brecciated limestone is 3-7%); but as to the reservation of petroleum, the breccia evidently can not be the oil reserving layer. Actually, each exploration area of petroleum and the equivalent hard gypsum layer of brecciated limestone are , on the contrary, the dividing layer of oil and gas.

4. When the stone layer becomes gently sloping, the mineral layer on the soluble stone can be broken apart due to "K'o-szu-t'e" collapsing.

5. The brecciated limestone is loosely stuck together, and it dissolves easily on a ground surface with good permeability (Photo 7). Springs rarely appear at a district of ground breccia limestone. At T'ien-fu and Chung-liang-shan coal mines, the revealing water point was distributed mostly near the lower part in the breccia. Therefore, we can say that the hard gypsum mixed with dolomite and limestone in the deep underground of the Chia-ling River system is a relatively non-permeable layer, while on the ground surface the breccia limestone produced later in an equivalent layer position is a relatively permeable layer.

6. There are over 10 hot springs in the vicinity of Chung-ch'ing (Fig. 1). Their water temperature is usually 30°-45°C; their water quality is calcium of sulfuric salts, with mineralizability of about 1.8-2.8 g/l, making it a saturated gypsum water. These hot springs are not merely distributed in the district of brecciated limestone at Chung-ch'ing but also where brecciated limestone appears at Szechuan. Therefore, we consider this type of hot spring near Chung-ch'ing to be the deep products of "K'o-szu-t'e"gypsum, the twin to brecciated limestone.

7. The big, water conservatory projects of the Yangtze River and Chia-ling River were constructed in the valleys of Szechuan basin. The brecciated limestone of the Chia-ling River system is commonly distributed in valleys inclined in structure. This breccia is loosely combined and, therefore, is not suitable for the foundation of a high dam (based on experimental results, the limestone of the Chia-ling River system has a compressibility of 700-1400 kg/cm^2, while the brecciated limestone only about 500-800 kg/cm^2).

Based on the drilling results at Mao-erh-hsia, the rock center availability of this breccia was only 40-70%; after the breccia had seriously dissolved (Photo 8), the rock center showed a bee-hive structure, even below 100 m. Based on the water pressure experimental results, this brecciated limestone usually had large permeability. Its unit absorbability reached 0.1-1.0 l/min; it did not show appreciabily a decrease as the depth increased; even 100 m below the river bed could not be considered to be a relatively non-permeable layer. Since this brecciated limestone has a great permeability, when construction is made in this breccia district or in nearby districts, engineering steps to prevent leakage around the dam or foundations of the drainage system must be taken.

References: /Russian names have been transliterated/
1. Heim, A. ; Geological structure and petroleum in the vicinity of Chung-ch'ing, Szechuan, 1931.
2. P'an Chung-hsiang (3382 6988 4382) and P'eng Kuo-ch'ing (1756 0948 1987) ; Chi-chiang river bed in South Szechuan, 1939.
3. Li Ch'un-yu (2621 2504 3558) etc.; Geology of Hua-hsiung-shan, 1943.
4. Li T'ao (2621 7118) and Lo Cheng-yuan (0925 2973 6678); Geological mineral products at north bank of Yangtze River between Pei-ling Ch'ang-shou Chung-hsien Liang-shan, 1943.
5. Hou Te-feng (0230 1795 1409); Geology of Shih-chu Chien-chiang and its neighboring districts, 1944.
6. Hou Te-feng ; Geological minerals in north Kweichow, 1945.
7. Hsiung Yung-hsien (3574 3057 0341); Gypsum mine of the Triassic Period in east Szechuan, 1949.
8. Ho Ch'un-sung (0149 2504 5549); Outlines of Chinese gypsum minerals data, last issue.
9. Chinese Geological Map (1/1,000,000), Chung-ch'ing sheet, 1950.
10. Li Hsing-hsueh (2621 2502 1331) and Sheng Chin-chang (8518 6855 4545); Gypsum and coal of Ming-hsien-ts'un of T'ai-yuan Hsi-shan.
11. Ground layer table of Chinese district (manuscript), 1956.
12. Lo Chih-li (0925 1807 4539); Research report on Triassic system of Ya-nan, 1956.
13. Lo Chih-li; Preliminary discussion on layers and its rock phase of Triassic system in Szechuan basin, 1957.
14. Yu. A. "Ko-hsi-chin"; Ground structural theory of the petroleum district, 1952.

15. A. Yu. "Ya-k'u-she-ya"; Examples of "K'o-szu-t'e" developed history on (Samarskaya River Bend), last issue, 1956.
16. V. P. "Ma-szu-lo-fu"; Comparison method of rock layer section of carbonic salts, Geological translation, 1957.
17. Geological data from Chung-liang-shan and Ch'uan-chi coal mine.

/Note: Photographs No. 1-8 were unclear and not able to be reproduced./

10,507
CSO: 1599-S/a

CONCERNING FURTHER SIMPLIFICATION OF "SOME THEORETICAL AND PRACTICAL QUESTIONS OF COMBINED PUMPING"

[Following is the translation of an article by Kao Chung (7559 6945), in Shui-wen Ti-chih Kung-ch'eng Ti-chih, No. 1, 12 January 1959, pp. 21-23.]

Prior to writing this article the writer studied the theses of "A-chia-pi-yeh-fu", Ko Liang-t'ao (5514 0081 7290), Kao Ching-liang (7559 2417 0081), Tseng Te-hsien (2582 1795 7359) and others. He thought that study of the subject topic would improve the experimental work and add new knowledge and methods for hydrogeological experimentation. Combined pumping can save material, raise the drilling efficiency and simplify the experimental procedure. With a desire to learn the writer presents some simplified, practical methods and procedures for mutual discussion.

I. Practical value of combined pumping in the present stage.

Combined pumping is a rather new subject, so its reliability and practical value are yet to be proved by actual performance. At the present stage most people do not dare adopt this new method, especially under large and medium scale conditions (1:50000 and above). The reasons are: (1) that the reliability is uncertain and (2) that during practical work, as analyzed by Kao Ching-liang, the total amount of work had not been reduced or only a little simplified (even increased the work . . . as Ko Liang-t'ao's method). Under small scale (1:200,000 and under) survey it should largely be adopted (10, 20 and 30 m manual striking, rotary drillings are now extensively used by Ho-pei, Sung-liao teams, etc.

1. Refer to the 9th and 11th issues, 1957 and to the 5th issue of 1958 of this publication.

Since this pumping test requires only one combined pumping (generally omitting the upper water layer) and one depth lowering, the methods described in the above mentioned theses are not applicable (required unknown factors, such as Ka or Sb, are lacking).

The writer considered practical conditions of the mentioned field teams to be accurate and to be a natural consequence. It should first be carried out in a shallow hole without individual layer pumping, and then, gradually to a deep hole with individual layer pumping, this to be replaced by the combined pumping method.

II. Demerits of Kao's and Tseng's methods.

1. The Kao Ching-liang Method.

(a) This method with great limitation applies only two self-flow water layers; the upper undercurrent layer is usually widely distributed and it frequently meets with three self-flow layers.

(b) This method requires the combined layer and the upper water layer to be pumped twice and also requires the drilling for water sealing to be stopped. Though simpler than Ko's method, Kao's method is still considered complicated and would slow down the progress.

(c) Since no derivation and proof of the value of average permeability K_{cp} has been written it is not valid to introduce K_{cp}.

$$K_{cp} = \frac{K_a M_a + K_b M_b}{Ma + M_b} \qquad (1)$$

Because the K_{cp} value will be directly affected by S_a, S_b and $S_a \neq S_b$, the more accurate equation should be:

$$K_{cp} = \frac{K_a M_a S_a + K_b S_b M_b}{M_a S_a + M_b S_b} \qquad (1a)$$

where K_a, M_a permeability and thickness of the first water bearing layer, respectively.

K_b, M_b permeability and thickness of the second water bearing layer, respectively.

S_a, S_b stable water levels, a and b, in the first and second water layers, related to the combined water level, a+b, raising or lowering.

2. Tseng Te-hsien's Method.

(a) Though requiring only one pumping this method still requires the drilling for water sealing to be stopped after it reaches the second water layer. This method retards progress and its operational process needs to be improved. If drilling is done directly to the second water layer and if combined pumping is started, the drilling and experiment can be done simultaneously without interference. This is advantageous to the drilling progress and operational procedure.

(b) The results from previous tests do not take into

consideration the affect of the K_{b} value in the lower water layer on the rock powder.

III. New method.

After drilling through two or three water layers, the stable water level of each layer (a, b and c) must have a certain relationship with the combined water level (a+b and a+b+c); i.e., there must be a function between them. If the water level, a, of the first water layer and the combined water level, a+b, of the first and second water layers, or the combined water level, a+b+c, of the three layers, represented the individual stable water level b and c in the second and third layers, our experiment would be greatly simplified. Then it would not be necessary to stop drilling for water sealing and to pump twice; moreover, pumping can arbitrarily be done in the first water layer or the first and second layer mixed. Besides, it would not limit the number of layers or the type of hydrodynamics (bearing or free). The functional relationship of a, b, c, a+b and a+b+c is computed by the following method.

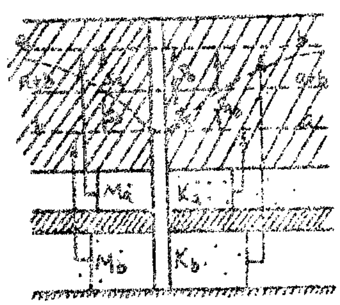


Fig. 1

(1) Under two water bearing layers (Fig. 1):
After the combination of the two water bearing layers:

then,

$$Q_a+b = \frac{2\pi K_a M_a S_a}{\ln R - \ln r_o} = \frac{2\pi K_b M_b S_b}{\ln R - \ln r_o} \qquad (2)$$

$$K_a M_a S_a = K_b M_b S_b$$

where: Q_a+b = the relative flow rate and amount absorbed of each the upper and lower water layer after the combined water level has been stabilized.

R = influential radius (neglect deviation of K value caused by different S).

r_o = radius of well hole.

Q_b = flow rate in the hole when lowering depth $S = S_a + S_b$.

If the water level drops to S_b while combined pumping is carried on, the equation then becomes:

$$Q_b = \frac{2\pi K_{cp}(M_a+M_b)S_b}{\ln R - \ln r_o} \qquad S_b\ (3)$$

$$= 2K_{cp}\,(M_a+M_b)$$

where: $\alpha = \frac{2\pi}{\ln R - \ln r_o}$

But b layer stops absorbing water at that time, so the submerged water amount is completely supplied by pipe a to get

$$Q_b = \alpha K_a M_a (S_a + S_b) = \alpha K_a M_a S_a + \alpha K_a M_a S_b \qquad (4)$$

From (2) we know:

$$Q_b = \alpha K_b M_b S_b + \alpha K_a M_a S_a = S_b (K_a M_a + K_b M_b) \qquad (4a)$$

Combining (3), (4) and (4a):

$$Q_b = \alpha K_{cp} (M_a + M_b) S_b = \alpha K_a M_a (S_a + S_b) = \alpha S_b (K_a M_a + K_b M_b).$$

$$K_{cp} = \frac{K_a M_a (S_a + S_b)}{(M_a + M_b) S_b} = \frac{K_a M_a + K_b M_b}{M_a + M_b} \qquad (5)$$

We know from the method of least square

$$K_{cp} = \frac{K_a M_a S_a + K_b M_b S_b}{M_a S_a + M_b S_b} \qquad (1a)$$

From the concept of Equation (2), it can be written as:

$$K_{cp} = \frac{K_a M_a S_a + K_a M_a S_a}{M_a S_a + M_b S_b} = \frac{\alpha K_a M_a S_a}{M_a S_a + M_b S_b} \qquad (1b)$$

From (5) and (1b) we get:

$$K_{cp} = \frac{K_a M_a (S_a + S_b)}{(M_a + M_b) S_b} = \frac{\alpha K_a M_a S_a}{M_a S_a + M_b S_b} \qquad (6)$$

$$2 S_a S_b (M_a + M_b) = (S_a + S_b)(M_a S_a + M_b S_b) \qquad (6a)$$

Developing (6) into a quadric equation:

$$\xi S_b^2 + \lambda S_b + \xi S_a = 0.$$

$$\varepsilon = \frac{M_b}{M_a + M_b}$$

$$\xi = \frac{M_a S_a}{M_a + M_b}$$

$$\lambda = (\xi + S_a \xi - 2)$$

In this equation, only S_b is unknown, therefore, we solve

$$S_b = \frac{-\lambda \pm \sqrt{\lambda^2 - 4\varepsilon\xi}}{2\varepsilon} \qquad (6b)$$

We use only the positive value because S_b is considered to be a positive value.

From the above equations, we can compute the unknown S_b by the known values M_a, M_b and S_a (equation 6b). Then, perform the combined pumping only once (if necessary, or pumping once in each layer); the value K_a or K_{cp} can be obtained from equation 6. Finally, equation 2 is used to solve K_b.

(2) Under three water bearing layers (Fig. 2):

The simplest method is to find S_a, S_b, K_a, and K_b by the method given above. Consider the first and second layers as a combination of the first and third and compute S_c, K_c etc.

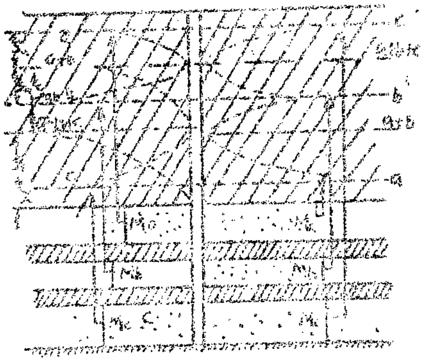


Fig. 2

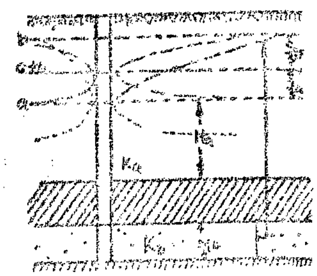


Fig. 3

(3) If the first layer is undercurrent:

When the upper portion is undercurrent, the above method can still be perfectly applied. However, the following concept should be understood: The equation for the integral hole of the undercurrent is (Fig. 3):

$$Q = \frac{\pi K_a(2H_a - S_a)S_a}{\ln R - \ln r_0}$$

where: H_a = thickness of undercurrent layer.
It may be changed to:

$$Q = \frac{2\pi K_a(H_a - \frac{1}{2}S_a)S_a}{\ln R - \ln r_0} =$$

$$= \frac{2\pi K_a M_a' S_a}{\ln R - \ln r_0} = \alpha K_a M_a' S_a$$

where: $M_a' = (H_a - \frac{1}{2}S_a)$ is an introduced thickness; it is a known value because S_a and M_a' are known.

Under stable water level:

$$Q_{a+b} = \frac{2\pi K_a M_a' S_a}{\ln R - \ln r_0} = \frac{2\pi K_b M_b S_b}{\ln R - \ln r_0}$$

Under mixed water pumping

$$K_a M_a' S_a = K_b M_b S_b \ldots\ldots\ldots\ldots \quad (2')$$

When water level of b layer is higher than that of a layer and let $S = S_a$:

$$Q_a = 2\pi K_{a+b}\frac{(M_a' + M_b)Sa}{\ln R - \ln r_0} = \alpha K_{a+b}(M_a' + M_b)S_a \qquad (3)$$

At this time, water absorption of a layer $\rightarrow 0$, and b layer becomes all indraft water.

$$Q_a = \frac{2\pi K_b M_b(S_b + S_a)}{\ln R - \ln r_0} = \alpha K_b M_b(S_b + S_a) \qquad (4)$$

so, we get:

$$= \alpha K_b M_b S_b + \alpha K_b M_b S_a = \alpha K_a M_a' S_a + \alpha K_b M_b S_b \qquad (4a)$$

to get:

$$K_{a+b} = \frac{K_b M_b (S_b + S_a)}{(M_a' + M_b)S_a} = \frac{K_a M_a' + K_b M_b}{M_a' + M_b} \qquad (6)$$

Similarly, by the method of least square:

$$K_{cb} = \frac{K_a M_a' S_a + K_b M_b S_b}{M_a' S_a + M_b S_b} = \frac{2K_b M_b S_b}{M_a' S_a + M_b S_b} \qquad (1a')$$

This says that the above method can be perfectly applied when b is higher than a.

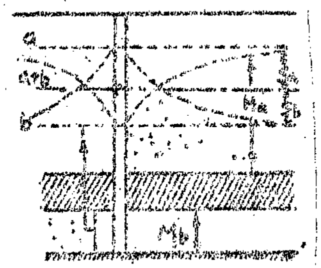


Fig. 4

When water level b is lower than a (Fig. 4), assuming the combined pumping $S = S_{ab}$, the thickness of undercurrent H_a will be equal to $(H_a - \frac{1}{2}S_{ab})$; since S_{ab} is unknown, M_a' is unknown. Under such conditions the above method can be theoretically applied, but it is rather complicated. The best way to do this is to let $S = S_a$ during the pouring test. The purpose for pouring the water is to make water level b higher than water level a so that the combined pumping method can be applied as above. If the water pouring test is not applicable, the pumping test can still be done. Then the value S_b should be calculated by the following equations:

$$K_{cb} = \frac{K_a M_a''(S_a + S_b)}{M_a' + M_b} = \frac{2K_a M_a' S_a}{M_a' S_a + M_b S_b}$$

$$式中: M_a' = (H_a - \frac{1}{2} S_b)$$

$$M_a'' = [H_a - \frac{1}{2}(S_a + S_b)]$$

$$r S_b^2 + q S_b - t = 0$$

$$S_b = \frac{-q \pm \sqrt{q^2 + 4r \cdot t}}{2r} \qquad (1b'')$$

$$r = [H_a M_b - \frac{S_a}{2}(+H_a + 1)]$$

$$q = \{ S_a(H_a(H_a - \frac{S_a}{2} + M_b + 2) - \frac{1}{2} + M_b) - \frac{M_b}{2} \}$$

$$t = S_a H(2H_a + 2M_b - S_a H_a + \frac{1}{2})$$

This method further simplifies the combined pumping method; it simply operates by pumping without the water sealing process to observe the water level of the next layer and without pumping twice each layer and each combined layer. Its accuracy is no less than that of "A-chia-pi-yeh-fu"'s. This method not only saves national expenditures, but also promotes the drilling efficiency.

10,507
CSO: 1599-S/b

METHODS AND PRINCIPLES OF FORECASTING RESERVOIR WALL COLLAPSE AND SOME REFERENCE DATA

[Following is the translation of an article by Sun Kuang-chung (1327 1684 1813), in Shui-wen Ti-chih Kung-ch'eng Ti-chih, No. 1, 12 January 1959, pp. 24-26.]

When a reservoir is built on a river course where its bank is composed of loose sediments, bank sliding frequently occurs as a result of water flowing from the river to the reservoir, where the water surface is wide and the wave action is greatly increased. It is necessary to predict the possible development of bank sliding in the reservoir design in order to make an economical evaluation, to plan availability of the land above the reservoir wall, to consider the necessary method to prevent sliding, etc.

In predicting the collapse of the reservoir wall, it is not enough to work out the possible development of only the final sliding of the bank; it is important to predict the possible development of bank sliding for water reserved in different years.

The methods of predicting the possible development of reservoir wall collapse in different years has been described by the writer in his paper, "Problem in Predicting the Method of Reservoir Wall Collapse at a Downstream District". The subject article presents some points to supplement the methods mentioned in his previous paper and also recommends some reference data.

The principal factors of the external force causing reservoir wall collapse are wave action, water level variation and atmospheric wind action.

Wavo action is the principal external force that develops reservoir wall collapse, especially in forming the flat. Water level is the basic condition for wave action. Atmospheric wind action is the principal external force that forms

a stable bank appearance after the reservoir wall collapse.

The appearance of a stable bank, the extent of collapse, and the speed of the collapse are determined by the above factors of external force after the reservoir wall collapse. They are also determined by the structure of the reservoir wall (topographical characteristics of the bank), geological structure and conditions for protection against collapse.

In order to find the possible developing extent of the reservoir wall collapse in different years, it is necessary to understand the variations of the bank appearance during collapse, the relationship between the collapsed material and the sedimented material, and the revealing order of its collapsing speed.

The bank appearance formed after the reservoir wall collapse may be divided into three parts according to the action of external forces and topographical characteristics:

1. Bank - located above the high water level of the reservoir; raised by the wave action; this part is not subject to wave action.
2. Flat - located between the high and low water levels of the reservoir; a result of wave action.
3. Sedimented slope beneath the flat - located below the low water level of the reservoir; this part is also not subject to wave action, being formed under quiescent conditions.

During the reservoir wall collapse the bank gradually fell and its slope accordingly flattened. The material falling from the bank into the water piled up forming the sedimented part of the flat; the flat extended from both ends and its slope became gradually flat. Then the sedimented slope beneath the flat gently moved toward the reservoir. During the displacement, its slope was a constant.

After the bank fell in the first stage of the reservoir wall collapse, the new slope was steep in critical equilibrium of the bank soil. When plotting this new slope in predicting the reservoir wall collapse, it is not necessary to determine the slope by complicated formulas of soil mechanics, as it can be roughly determined by the data in Table 1. Thus, the result of predicting will not be affected very much.

Table 1. Critical equilibrium slope of the bank in the first stage of reservoir wall collapse.

Composition of bank	Clay	Stony-clay	Stone between clay	Clayey fine sand	Clay & fine sand layers	Fine sand between stone	Loam	Silt	Sand-clay
Slope	80°-90	80-85°	80-90	60-70°	70-80°	70°-80	80-90°	75-85°	50-60°

During the reservoir wall collapse the slope of the bank gradually changes from steep to flat. To predict the reservoir wall collapse the difference of the critical equilibrium slope and the final stable slope is divided into several equal divisions (usually 9 equal divisions) representing the variation during that period.

The flat appearance complicatedly changes during the collapse. When the water level temporarily becomes stable at a certain height, the reservoir wall under the wave action is quickly shaped into a stable flat appearance; when the water level changes, the flat appearance will be damaged by water action making a new temporarily flat appearance. Thus, during the whole course of the collapse the flat repeatedly developed into a trapezoid shape, and its slope gradually became flat and smooth in appearance. In order to simplify the predicting, the flat appearance of any stage during the collapse may be assumed to be a smooth curve.

Based on the actual data analysis from the wall collapse observations at Kuan-ting Reservoir, it was found that under a constant water level the flat appearance with respect to wave action (from the highest point of the waves to the influential depth of the wave action beneath the water level) can be represented by equation (1), which is a curve.

$$x = 10^{\frac{y-h_H}{K} + \log\frac{0.4343K}{m_2}} - 10^{\log\frac{0.4343K}{m_2} - \frac{h_H}{K}} \qquad (1)$$

The point of origin of the curve of equation (1) is located at the intersection of the high water level and the slope of the wall section. The curve is considered to be positive toward the reservoir on the X-axis and positive downward on the Y-axis. The K value in the equation is a coefficient that can be computed from equation (2):

$$K = \frac{H}{\log\frac{m_2}{m_3}} \qquad (2)$$

where h_H = height of wave; can be computed by "Ju-k'o-fu-szu-chi"'s formula or by approximation by using $\frac{1}{2}$ wave height.

H = influential depth by wave action; can be computed by N. E. "K'ang-te-la-chieh-fu"'s formula or, approximately by using 2.5h, h as wave height.

m_2 = coefficient of flat slope atwater edge; m tan ; is the sloping angle of the flat at the water edge and can be obtained from Table 2. Table 2 was compiled from Kuan-ting reservoir observations and data from E.G."K'a-ch'iu-chin" and V.V."Po-li-ya-k'o-fu".

m_3= coefficient of flat slope at influential depth; $m_3 = \tan \gamma$; γ is the sloping angle of flat at influential depth. The angle is a function of material composition and wave height. γ can be obtained from Table 3 when the reservoir is composed by clay, sand-clay and fine sand.

Table 2. Relationship of wave height and stable slope beneath water at edge of the flat.

Soil type / Slope / Wave height	Loam	Clay	Silt	Fine sand	Medium sand	Silt with gravel	Coarse sand	Stone	Gravel
0.5m	4°30'	6°	8°	10°	12°	13°	14°	16°	20°
1.0M	2°30'	4°	5°	7°	8°	9°30'	11°	12°	14°
1.5m	1°30'	2°	2°30'	4°	5°	7°	8°	9°	10°
2.0m	40'	50'	1°	2°	3°	5°	6°	7°	8°

Table 3. Relationship of wave height and the flat slope at critical water depth under wave action.

Wave height	0.5	1.0	1.5	2.0
Slope	40'	1°20'	1°	30'

The overall appearance of the flat under variable water level conditions was evidently formed by the combination of flat appearances under a constant water level. The upper portion of the overall appearance of the flat under high water level by wave action can be represented by the curve of equation (1), the lower portion of which becomes a continuous flat curve from the end of the upper portion. In order to simplify the work for predicting collapse, the lower portion may be assumed to be a straight line; its selected slope should agree with the flat slope under high water level.

As mentioned above, the flat slope is equal to the reservoir wall slope, which follows the flat gradually extending from steep to flat. The flat appearance obtained from the data in Table 2 and Table 3 represents the flat appearance of the final stable shape; the slope shaped by any stage during the collapse is greater than the stable flat appearance. The flat appearance shaped by any stage during the collapse can be computed by assuming that B is the final flat width of the influential depth under the high water level wave action and that B' isthe original width of the bank slope at a relative height. The difference B -B' is then divided into

several equal divisions (usually 10 divisions) to plot the curve. It should be noted that the number of divisions should be in agreement with the number of slope variations of the bank in order to plot the overall appearance of the reservoir wall.

After the appearances of the bank and flat during the collapse are plotted, the curves of the assumed bank appearance and the flat appearance of the relative stage are connected and the lower portion is plotted according to the sedimented slope beneath the flat. Then the possible overall appearance of the reservoir wall can be obtained in any stage during collapse.

The sedimented slope beneath the flat is related only to the above described characteristics. Its angle generally varies between 18° and 20°. During this portion of external shape plotting, it is suggested that 18–20° be used for silt, 20–22° for sand-clay and fine sand, and 23–24° for sand-clay.

After the variation of the external shape of the reservoir wall during collapse is plotted, the method for determining the position of the reservoir wall section in any stage during collapse is further studied. To solve this problem it is necessary to clearly understand the relationship between the material from the flat sedimented portion and that from the bank falling portion.

During collapse the bank was damaged. The damaged material was carried by wave action into the water, thus forming the sedimented portion of the flat. During the sedimentation the fine particles of the damaged material were carried away by wave action into deep water located beyond the flat; the soil density became higher or lower in accordance with the new sediments (in most cases the density decreases). For this reason the relationship between the sedimented volume of the flat and the original volume of the bank falling portion can be represented as equation (3), where f is the coefficient of sedimentation.

$$f = \frac{V_2}{V_1} = \frac{\delta_1}{\delta_2}\left(1 - Q_{dx} + q_{dx}\right)$$

where V_1, δ_1 = volume and specific gravity of the original soil in bank falling portion.

V_2, δ_2 = volume and specific gravity of the sedimented flat portion from V_1.

Q_{dx} = amount of particles with a diameter less than dx; of average composition of original soil in bank falling portion; in decimals.

q_{dx} = amount of particles with diameter less then dx; of average composition in flat sedimented portion; in decimals.

δ_1 and $Q_{dx} = 0.01$ was obtained by observing the predicted reservoir wall collapse.

Based on some data analysis, the specific gravity of the flat sedimented portion can be selected from the data in Table 4.

Table 4. Specific gravity of the flat sedimented portion.

Soil type	Loam	Silt	Silty-clay	Sand-clay	Sandstone
Sp. grav. δ_1	0.9-1.0	1.0-1.1	1.1-1.2	1.2-1.3	1.35-1.45

q_{d2} is hard to determine. Based on some limited analysis, the amount of particles in the flat sedimented portion that are less than 0.019 cm in size and formed by wave action of 1.5-2.0 wave height is generally 10-20%. Therefore, Table 5 is recommended for reference in computing q_{d2} for the coefficient of sedimentation.

Table 5. Amount of particles less than 0.01 cm in size in the flat sedimented portion.

Soil type	Loam	Silt	Silty-clay and fine sand	Medium size sand	Coarse sand	Sandstone
q_{d2} value	0.2	0.2-0.15	0.15-0.1	0.1-.05	05	05

Thus, when all values of δ_1, δ_2, Q_{d2} and q_{d2} are known, it is easy to find f, the coefficient of sedimentation. For example, the density of the original soil in clayey-sand soil $\delta_1 = 1.5$; the amount of particles of average composition in the bank that are less than 0.01 in size is 65% or $Q_{d2} = 0.65$; using $\delta_2 = 1.2$ and $q_{d2} = 0.15$, the coefficient of sedimentation is:

$$f = \frac{1.5}{1.2}(1 - 0.65 + 0.15) = 0.625$$

It should be pointed out that the calculated coefficient of sedimentation applies only if the bank has not been cut by flowing ditches. Therefore, correction should be made when the bank is cut by flowing ditches.

After the coefficient of sedimentation is calculated, let the ratio V_1 and V_2 be equal to f. Then the position of the reservoir section after collapse in that stage is equal to the computed ratio. Next, the functional curve can be obtained from the volume of the bank falling soil and its back distance at different stages after the collapse. If the possible falling volume of the bank soil at any period of water in the reservoir is known, the extent of fall of the bank in that period can be easily obtained by using the plotted curve.

The possible falling volume of the bank soil in any year of preserving water in the reservoir V_t can be calculated from equation (4).

$$V_t = V_0 \left(1 - e^{\frac{t}{t_1} \ln \frac{V_0 - V_1}{V_0}}\right) \qquad (4)$$

where t = time of the predicted reservoir wall collapse, in years.

V_0 = final or maximum falling volume of bank soil, in meters.

t_1 and V_1 = time and volume of the falling soil of the bank, which are known in the beginning of the collapse.

Table 6. The falling volume of bank soil for preserving 4 years of water at 10 m height of the reservoir bank.

Soil type / Wave height in meters	Yellow clay	Fine sand	Medium sand	Silt	Silt with gravel	Loam	Loam with gravel
0.5	110	58	40	32	26	20	16
1.0	220	82	58	44	38	32	26
1.5	280	100	72	53	44	38	32
2.0	320	113	80	60	50	43	37

h' = the predicted bank height of the reservoir, which is less than 10 meters.

Value V_1 can be chosen from Table 6, which gives the falling volume of the bank soil for preserving four years of water, with a bank height equal to or greater than 10 m. The values in Table 6 are based on the data of E. G. "K'a-ch'iu-chin" and the observed data from the reservoir wall collapse of Kuan-ting Reservoir.

When the bank height is less than 10 m, the falling volume of the bank soil for preserving four years of water should be computed by equation (5) instead of equation (4).

$$V_h' = V_{10} \frac{h'}{10} \qquad (5)$$

where V_h' = the falling volume of bank soil for preserving 4 years of water at predicted height of reservoir bank.

V_{10} = the falling volume of bank soil for preserving 4 years of water at 10 m bank height. Use values in Table 6.

Based on the above described method and some recommended reference data, the extent of developing collapse can be predicted when water is preserved in the reservoir for one year. This method, as far as its accuracy is concerned, can be applied to the preliminary design of a water reservoir for studying problems on reservoir wall collapse.

10,507
CSO: 1599-S/c

ENGINEERING GEOLOGY SURVEY OF ERH-HAI AQUEDUCT TUNNELS

[Following is the translation of an article by the Yunnan Provincial Bureau of Geology, in *Shui-wen Ti-chih Kung-ch'eng Ti-chih*, Number 1, 12 January 1959, pp. 27-29.]

Introduction

Erh-hai water introducing engineering is one of the important hydraulic engineering works in Yunnan province, and it is also the principal engineering work for irrigation in Ta-li-pai-tsu Autonomous Chou. The subject engineering consists mainly of three aqueducts: Erh-chi-ping (introducing water from Erh-hai to Ping-ch'uan), Erh-chi-wei (introducing water from Erh-hai to Wei-shan) and Erh-chi-teng (introducing water from Erh-hai to Teng-ch'uan). Among them, the Erh-chi-ping aqueduct, totalling 5.7 km in length, is the longest aqueduct so far in our country. The construction of the three aqueducts will irrigate an area of more than 500,000 mou for cotton, sugar cane, rice and other products. Besides, its water level head loss can be utilized for producing electrical power.

It was the hope for hundreds of years to carry out the subject engineering by the people in Ta-li-pai-tsu Autonomous Chou, but it was impossible to carry out the engineering under our old social system before liberation. After liberation, the People's Government made a preliminary survey for the project, and decided to begin construction by the late period of "the Second Five-year Plan". However, under the suggestion of provincial representatives for water conservacy of the two-year plan, the subject project was decided to be started in 1958. Owing to the limited time available, we adopted the policy of doing survey, design and construction simultaneously. Though the geological conditions for construction of the aqueducts were complicated and technical

equipment was insufficient, the people have offered their utmost efforts so that within a short period and as of this date, the work of surveying and designing have been largely completed and construction has been extensively undergone. We are strongly assured that the project will be completed by spring of the coming year.

General Description

Erh-hai is a large lake in west Yunnan, with steep mountains of 4020 m high in thewest and mountainous ridges of 2800 m high in the east. The mean water level of Erh-hai is 1974 m with a total capacity of 3,300,000,000 cubic meters.

Geological surveys of this district were rarely done in the past. It is located at the east edge of the Tien-mien /Yunnan-Burma/ earth belt and has frequent diastrophism; its rock phase varies greatly and a large amount of various igneous rock moves into the district. The Ta-li-erh-yuan Line along Erh-hai has several large, deep fissilities. West of the Line is mainly composed of gneiss and crystal schist; east of the Line, the ancient and middle age ground layers appear with extensive folds and structural cleavages. Construction of aqueducts might meet a great deal of structural broken belt zones and underground water of "Ko-szu-t'e" limestones.

In the district, mantle rock is easily broken by wind, and the streams are well developed; there are landslides and collapse, too. Ta-li is the earthquake center of West Yunnan; the severity of earthquakes reaches 8-9 grade according to the Russian standard. The earthquake effects dictate further strengthening of the aqueduct construction.

Based on the above reasons, the geological condition of the Erh-hai aqueducts engineering is rather complicated. According to instruction from the provincial representatives and the Provincial Bureau of Geology, we carried out the geological survey of the aqueduct project. We started the line-selecting survey, accompanied by the Water Conservatory Bureau in March; then, following the line, we made the engineering geological survey since May, which mainly includes 1/5,000 to 1/20,000 engineering geological survey, drilling and sample testing.

It wasinstructed that the project should be carried out at the earliest possible date, so we boldly simplified the survey procedure and reduced the amount of drilling work. Under the leadership of local authorities, the Provincial Bureau of Geology and the support of our people, we overcame difficulties with revolutionary spirit and rapidly completed the overall engineering geological survey of the Erh-hai aqueduct project in October.

Erh-chi-ning Aqueduct

This aqueduct is situated in Hai-tung-hsien at the east edge of Erh-hai. The preliminary survey indicated that geology of this district is very complicated; it is stratified with sand-shale and agglomerate of the Au-tao Period, limestones of the Shih-tai Second Period and igneous of the Second Period. Besides, there are many quartzite, granite and greenstone penetrating into the stratification. The largest broken zone of fault reaches 100 meters and small folds and faults can be seen everywhere. Despite the complicated geological conditions and on account of the speedy line-selecting for earlier construction, our preliminary survey made only a 1/10,000 geological survey. However, we fully considered the geological characteristics in the district during survey and took into consideration those problems which effect aqueduct line-selection.

(1) To investigate the extension, broken condition, broken width of the principal structural broken zone and see whether it has been colloided.

(2) To distinguish the different district (section) where it is subjected to strong wind, where igneous invades most, where mantle rocks are broken, where rocks are harder and are covered with thick material, where it is integral and is covered with thin material.

(3) To investigate the amount of underground water in "K'o-szu-t'e" limestones and its distribution.

(4) To find out the distribution andresson for huge landslides and rushing streams.

With the above principles in mind, we finished a 1/10,000 geological map of 25 km (Ref. 2) in 7 group-days. Three lines of aqueduct were selected for comparison and the best line was finally decided upon for construction under the conditions that it passes through good geological localities and is the most economical, of course.

According to the specification requirements, the preliminary survey of geology for aqueduct engineering "should perform engineering geological survey, route survey, entrance section survey, permeability tests, and laboratory tests and analysis in order to obtain sufficient data for determining the best line of aqueduct". But for the purpose of "speedy line-selecting", we greatly simplified the working procedure by a simple geological survey without doing any drilling and testing analysis. From the viewpoint of working quality, as we kept the principal geological points in mind, the basic requirements can be assured. The selected line of the aqueduct has the following merits:

(1) It avoided the structural broken zone.

(2) The characteristics of rock mechanics along the aqueduct was superior than the other possible lines, and its

covering material was very thin.

(3) The hydrogeological conditions along the aqueduct were better than the other ones.

(4) No landsliding was present at the entrance part of the aqueduct.

(5) It was a shorter aqueduct distance and able to drill a leading vertical well for aiding the construction of the aqueduct.

After the line was selected, we started our detailed survey for obtaining engineering geological data of the aqueduct construction and strengthening, finally deciding on the positions or locations of the aqueduct entrance and the vertical well.

Our detailed survey was carried out in a very short time. However, in order to quickly evaluate the engineering geological conditions along the aqueduct with limited technical facilities, we had to greatly simplify the survey procedures.

Under the conditions of "speedy line-selecting", it was impossible to thoroughly understand the geological conditions along the aqueduct. Therefore, only the 1/5000 engineering geological survey (covering an area of 3.6 km^2) and the 1/2000 engineering geological cross-section survey of aqueduct were made at both sides along the 300 m selected line for aqueduct construction. The main object of the geological survey was to find out the structural faults, rock characteristics and hydrogeological conditions. Based on that survey, it was found that there were 11 big faults along the aqueduct line, among which the largest faults reached 500 m long and over 50 m wide of the broken zone. Many small faults and folds were not counted in. There were many kinds of mantle rocks along the line such as loamed fine sand, clayey sand, quartzite sand, shale sandy shale, limestone, schist, greenstone, etc. The rock phase changed greatly, and its characteristics of mechanics varied accordingly; the rock itself changed rather severely for structural reasons, and was penetrated by many igneous rocks so its cleavages were well developed and was easily broken by wind action.

Drilling work was done along the line of the aqueduct. According to the specification requirement, "when the depth of the line is within 100 meters, the distance between drilling holes should be 100-300 meters apart along the line; where the geological conditions are complicated, the distance should be reduced to 50 meters". Though the geological conditions along the line were complicated, we only made a small number of controlling drills of 600-1100 m apart without additional drilling holes even at the aqueduct entrance. The drilling holes were located where

(1) rocks were broken at the aqueduct entrance, and greenstones cut in;

(2) the broken zone of faults was greater and the broken zone of erosion occurred more;

(3) "K'o-szu-t'e" limestones could possibly be met;

(4) wind action was severe, and possible flowing sand layer.

Based on the above, we located only six drilling holes along the 5.7 km aqueduct line with the designed depth of 668 m. The original drilling hole design was 5 m beneath the aqueduct elevation, but it was changed to 5-10 m below the hard rock according to the actual situation. Therefore, most drilling holes had not reached the aqueduct elevation. During drilling, in order to satisfy the field requirements, the design was revised again to the actual depth of only 375 m.

The aqueduct elevation was designed 7 meters below the mean water level of Erh-hai; therefore, it was possible to meet "K'o-szu-t'e" water and underground water from the broken zone during construction, the underground water and flowing sand usually bringing disadvantages to construction work. For the purpose of understanding the underground water condition, a water pumping test was made for each drilling hole. But considering only a small amount of water in the layer, we did the water pumping test by lowering only once.

Since we did not have laboratory facilities in our team, we sent 10 rock samples to the Hydro-power Design Institute for testing. Based on their requirements, only the specific gravity, capacity, bearing power, and hardness coefficient were tested for the rock samples. Since the underground water quality in the district varied slightly, only 7 water samples were taken for water quality analysis.

The above work, under the limited, short time, basically satisfied the requirements of engineering geological data. During the survey, we constantly studied and analyzed the progress, and made suggestions to the Design and Construction Department for revision and to supplement the aqueduct project. For instance, the aqueduct entrance was originally designed in loose and soft sedimented layer of the Fourth Period. After discovering this condition, we suggested to move the location of the aqueduct entrance to the rock bed, to avoid collapse and settlement. Another example; based on the drilling results, we found that the original design of the vertical well was located in a broken zone of faults with flowing sand, and suggested a change in the location, and also recommended a better location regarding geological conditions for the vertical well and a location for an inclined well to the Design Department for comparison.

Erh-chi-wei and Erh-chi-teng Aqueducts

Erh-chi-wei aqueduct is located at Mo-hsien southwest of Erh-hai, and the geological conditions of this aqueduct

are simpler than the Erh-chi-ping aqueduct. The ground layer of this district consists of ancient crystal schist, limestone of the Mid Triassic Period, and sandy shale of the Upper Triassic Period. In the middle portion of the aqueduct district, there is a big fault in a rather fragmentary shape. The district is heavy with grass and trees and is covered with very thick material without showing rocks.

The Erh-chi-teng aqueduct is located at Teng-ch'uan Ma-szu-p'o northeast of Erh-hai. Its geological condition is the simplest among three. The ground layer of this district consists of Yuan-wu stone of the Erh-hsia Period where no structural broken zone existed.

The line of the Erh-chi-wei Aqueduct was selected directly after reconnaissance survey without a preliminary survey. A 1/10,000 geological survey covering 20 km^2 was made in the aqueduct district. Based on the geological structure, rock characteristics and data on the stability of the entrance of the aqueduct, a shortest line of 4.5 km was selected. Many diggings for geological investigation along the line were performed which did not reach the expected results because it was covered by a very thick layer. Under such conditions the geological survey should emphasize the following problems:

(1) Investigation of the principal faults and their broken zones;

(2) finding the dividing line of the big rock systems;

(3) understanding thoroughly the stability of the area around the entrance of the aqueduct.

After the geological survey it was found that the selected line had avoided the broken zone of the faults; therefore, the rocks along the line were not subjected to severe structural breaking. However, the rocks near the surface of the ground were easily worn by wind action upon the broken pieces. In order to know the condition of the wind action and its influential depth, a drilling hole of 40 meters deep was designed at the river valley intersecting area in the middle of the line. No other experimental work was performed.

The survey of the Erh-chi-tang aqueduct was completed in a day. A 1/10,000 geological survey and a 1/5000 geological cross-section survey were made at both sides, each 300 m, along the selected 3 km line of the aqueduct. Since the geological conditions of the distrect were simple, we did only a few diggings for the geological investigation to find the following main points:

(1) The thickness of the covering matérial at the entrance area of the aqueduct and its stability;

(2) the dividing line of the Yuan-wu rock system in the ground layer.

Drilling work and tests were neglected.

From the above geological survey procedures and descriptions of the two aqueducts, the requirements of specifiation had been greatly simplified. The survey work was basicly divided into two steps:

(1) Reconnaissance Survey-line proposal: In this stage it is necessary to understand only the geological conditions of the aqueduct area and to plot a geological map of small scale for line proposal.

(2) Simplified Survey-line evaluation: In this stage a geological survey is performed according to the proposed line to find the principal engineering geological factors that effect construction and strengthening of the aqueduct. Then the line is decided.

This method of survey is applicable to places where geological conditions of the construction of the aqueduct are rather simple. It basicly satisfies the required data in a very limited time for a "speedy line proposal" and a "speedy line evaluation".

Principle Demerits

As mentioned above, the geological surveys of the Erh-hai aqueducts were performed in a very short time. The merit of the survey is that is greatly simplified the procedure and its content, resulting in the principle of "speedy line proposal" and "speedy line evaluation". However, there are several demerits due to the fact that this was the first time this kind of survey was done by our team, who were not familiar with these survey procedures, did not have adequate equipment, and were limited by time.

(1) The detailed survey (line evaluation) had done few diggings. Therefore, the geological structure of each individual area could not be clearly understood, this affecting the best location of the drilling holes. For instance, Holes #8 and #9 did not reach the objective of revealing the broken zone and "K'o-szu-t'e" water because of the inadequate location of the holes where the geological structure was complicated and few rocks were through the ground surface.

(2) The drilling quality was poor. Most of the drilling holes were located in areas subjected to structural breaking zones, erroded breaking zones, and strong wind action. Personel lacked practical drilling experience, which caused low efficiency in obtaining rock-heart of less than 30% from each individual drilling hole. The collected rock-heart was rather confusing in later order.

(3) Drilling efficiency was low. This was due to collapse of the hole wall, lack of necessary equipment, inadequate supply of equipment when broken. The maximum capacity of the drilling equipment was 125 m/month, this affecting the progress a great deal.

(4) Our team did not have equipment for the rock tests and the water analyses. The testings had to be done by other agencies. The delivery of the samples was difficult; more time was needed; the number of samples was limited also. Therefore, it was impossible to evaluate accurately the characteristics of rock mechanics along the line of the aqueduct entirely on time.

References: /Russian name has been transliterated/

(1) Geological temporary specification for hydraulic engineering (compiled by the Hydrogeological Research Institute and Bureau of Hydrogeology, 1957).

(2) Geological survey and research specifications for aqueduct construction, (I.L. "Pich- lei -1", translated by the Design Department of the Hydro-power Bureau, 1956).

10,507
CSO: 1599-S/d

GEOLOGICAL COMPUTATION "DISC"

/Following is the translation of an article by Chi Chih-T'ao (1323 0037 3447), in Shui-wen Ti-chih Kung-ch'eng Ti-chih, 12 January 1959, No. 1, pp. 29-32./

The first draft of this article was written in November, 1956 with a model of a geological disc. After revision in December, the article was presented to the 1956 technical conference at the Design Institute, concerning the subjects of engineering geology, hydrogeology, drilling techniques, electrical drilling and water soil analysis. The description and sample of Comrade Kuan En-wei's (7070 1869 1218) "Computation Disc for Geology" published in "Geological Knowledge", January, 1957, are largely similar to this article. In Kuan's paper, it is, however, not clearly described and the lines of the scale are rather confusing (the lines are partly overlapped; though two colors are used for scaling, it is still considered inconvenient), easily leads to mistakes and not convenient enough to compute the frequent applying equations. For example, in order to compute the oblique inclined angle on a section, it is necessary to turn the disc twice. The subject article was revised again in early 1959, presenting a better scale for replacing the general slide rule and various geological graphs and tables to save time in computation. Under the great development of socialistic construction, it is possible to benefit the development of geological field, especially engineering geological work which serves as the screw of the machine.

I. Theory and Construction of Discs.

Theory: The geological computation disc (abbreviated as computation disc) is theoretically similar to the general slide rule. It is made on the basis of logarithm functions which can be referred from the related books and will not be

discussed in this article.

Method of Construction: The computation disc is made of two discs (Fig. 1, inner and outer discs which are separated by the interval of the T scale and the n scale), and a sliding index (Fig. 2).

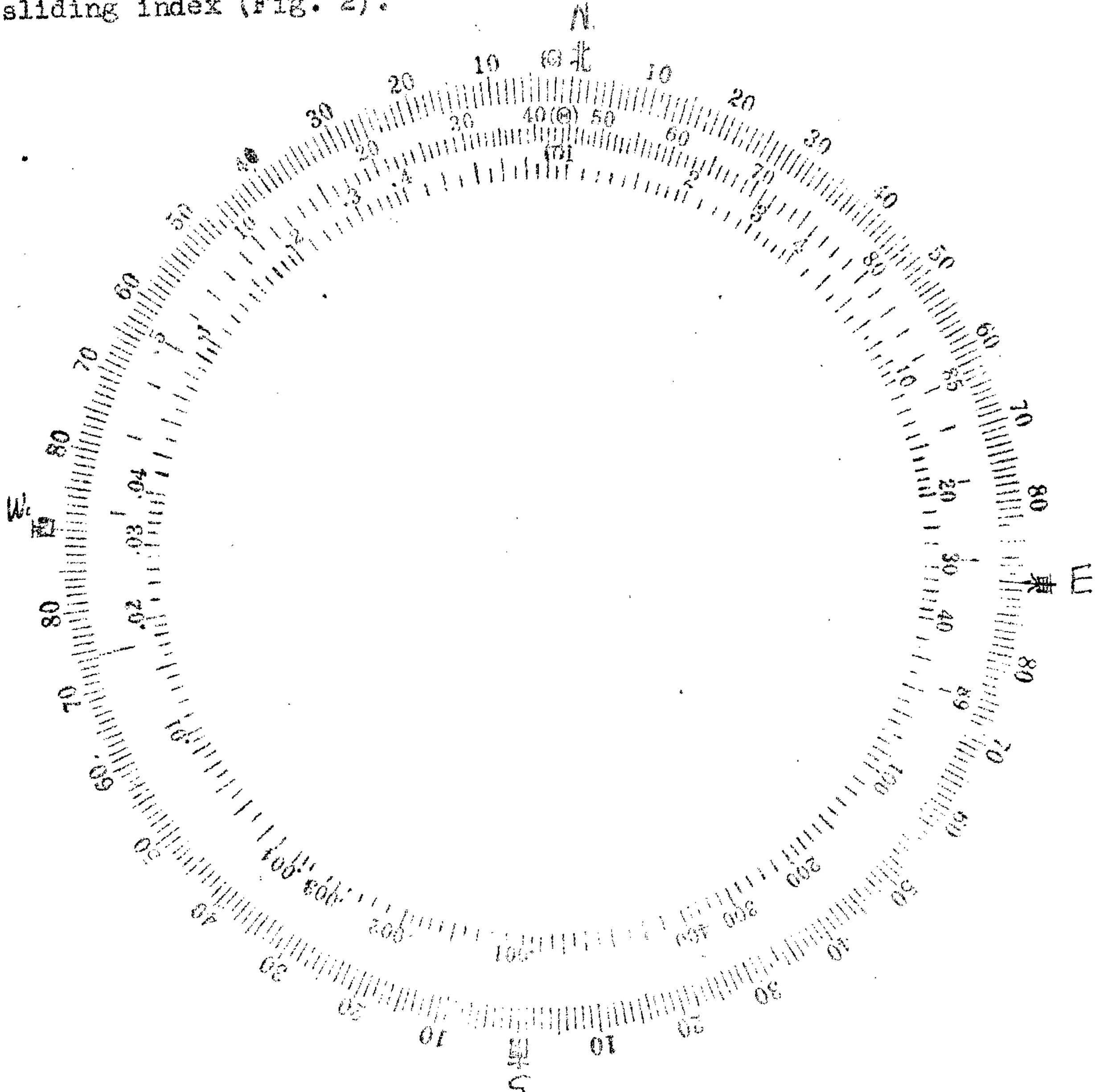


Fig. 1

In geological computation, we rarely use the value of csc, not even using csc. But for the convenience of calculation, we use the csc value for scaling instead of the sin value. Therefore, when the sin value comes into the

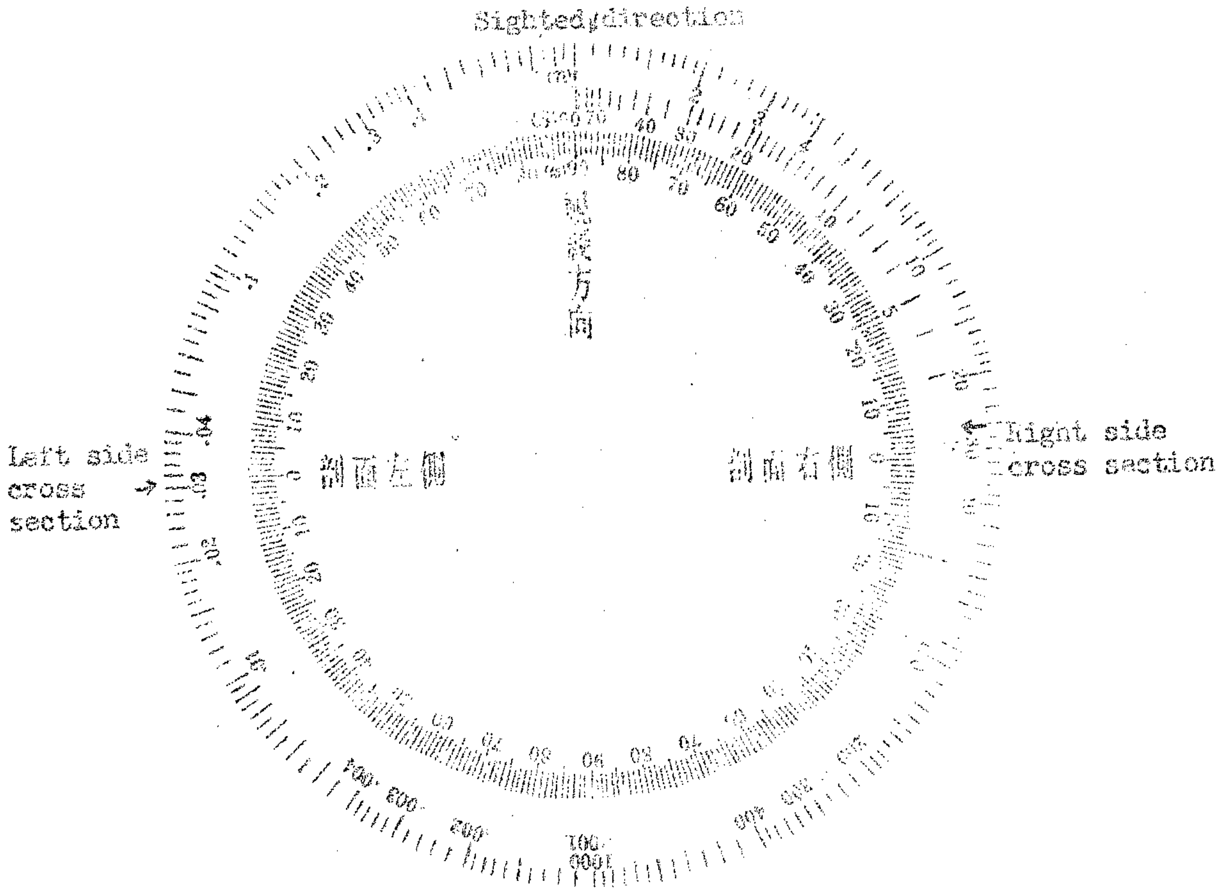


Fig. 2

calculation, we should use the 1/csc value instead; as a matter of fact, it is not necessary to change but to convert the multiplication into division during computation. When ctg and cos come into calculation, it is required to convert them into tan and sin for computation.

The size of the computation disc is optional, but for the convenience of carrying, it should not be too large. It is better to draw a large size print, and to take photostats for practical use. Thus, the computation disc is both accurate and convenient. The sliding index can be made of a celluloid sheet, and its size should be determined with respect to the computation disc, but its radius should be slightly greater than the graded scale of the outmost circle. On the sliding index, two fine lines should be marked a, perpendicular to each other and intersecting at its center O. When assembling, they should be placed on the same center (computation discs and sliding index).

II. Name of Scale and its application.

The outer circle of the outer disc is the "C" scale which is a direction scale in degree for computing the included angle of the ground section and the rock layer. Gradation of the scale is based on the circular angle of 360°.

The middle circle of the outer disc is the "Ø" scale which is an inclined angular scale for computing various false angles (including inclined angle revision and oblique inclined angle on the section). Gradation of the scale is based on the logarithm tangent.

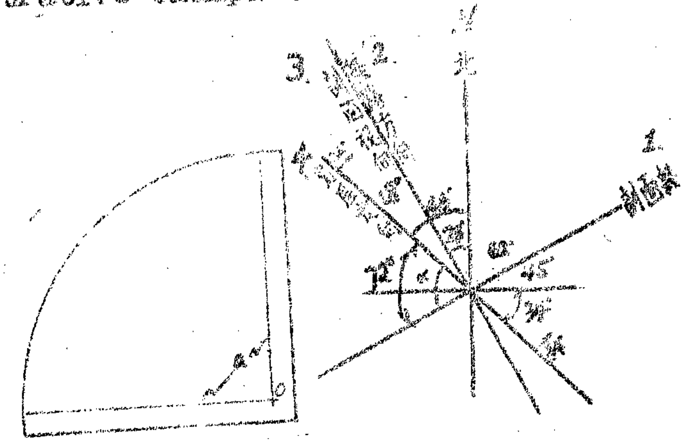
The inner circle of the outer disc is the "T" scale which is a real number scale for multiplication and division when operated with the "n" scale. But it should be noted that decimals are already marked on the scale. The scale is also a function scale of tangent, marked on the basis of the logarithm of numbers.

The outer circle of the inner disc is the "n" scale which is graded exactly as the "T" scale for calculating false inclined angle on a section when different scales are used.

The middle circle of the inner disc is the "S" scale which is the included angle between a section line and extended direction of the rock layer (known value). It is used for calculating false bearing angle and oblique false bearing anglecn a section. It is graded on the basis of the logarithm of reciprocal sine.

The inner circle of the inner disc is the "β" scale for calculating the included angle between the false bearing angle and the oblique false bearing angle. It is graded on the basis of the circular angle 360°.

III. Illustrative examples.



1. Section line
2. Line direction
3. Cross sectional sighting direction
4. Running direction of rock layer

Fig. 3

Ex. 1: As in Fig. 3, the directions of the line and rock layer being known, find out the false bearing angle of

the rock layer bearing angle on the section (i.e., the corrected bearing angle) and the oblique false bearing angle of the rock layer on the section with a vertical and horizontal scale ratio of 25.

Solution: Set 72° on the S scale (the included angle between rock layer direction and the section) opposite 34° on the Ø scale (rock layer bearing angle obtained in the field), and read 33° on the Ø scale opposite 90° on the S scale. 33° is the false bearing angle of rock layer on the section.

Move the sliding index to 25 on the n scale without moving the computation disc and read 86°30' on the Ø scale which is the oblique false bearing angle on the section with a vertical and horizontal scale ratio of 25.

Note: Formula for false bearing angle (from geological drawings): $tg\beta = tg\alpha\cos\omega$

where β = false bearing angle to be found.
α = bearing angle of the rock layer.
ω = the included angle between the rock layer inclination and the section.

In practice, we often use the included angle between extending direction of rock layer and the section Ø; therefore, the above formula can be written as:

$$tg\beta = tg\alpha\cos(90° - \theta)$$
$$= tg\alpha\sin\beta$$

To find the oblique false bearing angle of different vertical and horizontal scale, the formula is:

$$tg\beta' = ntg\beta$$
$$= ntg\alpha\sin\beta$$

where β' = oblique false bearing angle of the section with different vertical and horizontal scales.
n = the ratio of the different vertical and horizontal scales on the section.

For the purpose of accuracy and convenience in solving the oblique false bearing angle, the S scale is used, which is graded on the basis of log csc (it can reduce the operation of turning the computation disc once).

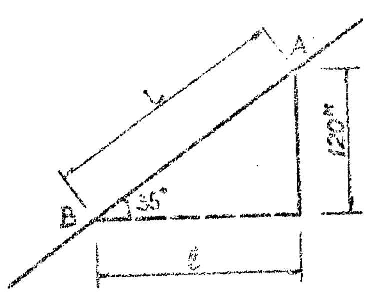


Fig. 4

Ex. 2: As in Fig. 4, when the height difference and ground slope between ground points A and B are known, what are the inclined distance L and the horizontal distance l between A and B?

Solution: Turn 1 on the n scale opposite 120 on the T scale and read the number on the T scale opposite 35° on the S scale.

$$L = \frac{120}{\sin 35^\circ} = 209.2 \text{ m.}$$

Using the S scale at 90° opposite 35° of the ∅ scale, find the number on the n scale which is pointed by 120 of the T scale.

$$l = \frac{120}{\operatorname{tg} 35^\circ} = 167.4 \text{ m.}$$

If the angle or number is too big or too small, the number can be adjusted by moving its digits and readjusted back after getting the answer.

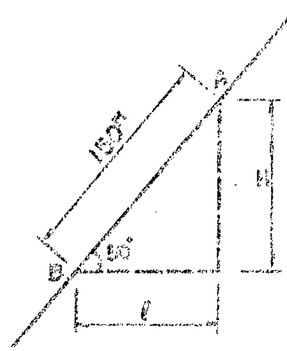


Fig. 5

Ex. 3: As in Fig. 5, when the inclined distance and its slope between two points A and B on the ground are known, what are the height H and horizontal distance l between the two points?

Solution: Using 40° of the S scale opposite 150 of the T scale, read the number on the T scale where 1 of the n scale points.

$l = 150\text{ m} \cos 50^\circ = 150\text{ m} \cos(90^\circ - 40^\circ) = 150\text{ m} \sin 40^\circ = 96.4\text{ m}$

Similarly, the H value can be found as:

$H = 150\text{ m} \quad \sin 50^\circ = 114.9\text{ m.}$

Ex. 4: As in Fig. 6, when the height difference and horizontal distance between two points A and B on the ground are known, what is the ground slope?

Solution: Set 66 of the n scale opposite 38 of the T scale; opposite 1 of the n scale, read 0.5757 on the T scale; opposite 90° of the S scale, read the number on the ∅ scale, which is the required ground slope.

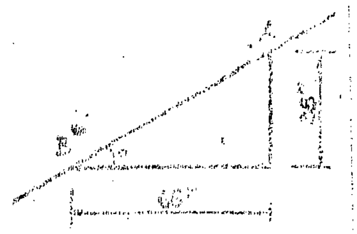


Fig. 6

$$tg\alpha = \frac{36}{66} = 0.5757$$

(Solving as Ex.4,5)

$$\therefore \alpha = 28°50' \approx 30°$$

Ex. 5: As in Fig. 7, when the height difference and inclined distance between two points A and B are known, what is the ground slope a?

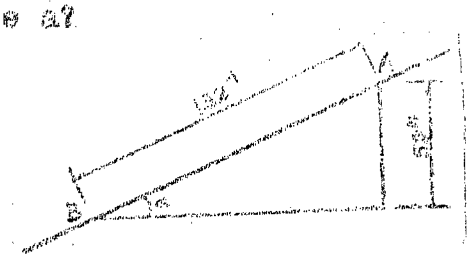


Fig. 7

Solution: Use 132 of the n scale opposite 52 on the T scale and, opposite 1 of the n scale, read 0.3939 on the T scale; then, opposite 45° on ∅ scale, read the number on the S scale.

$$\sin\alpha = \frac{52}{132} = 0.3939$$

$$\alpha \approx 23°15'$$

Ex. 6: As in Fig. 8, when the horizontal distance (perpendicular extending direction of the rock layer) and the bearing angle between two ground points A and B are known, what is the depth H of the rock layer at point A?

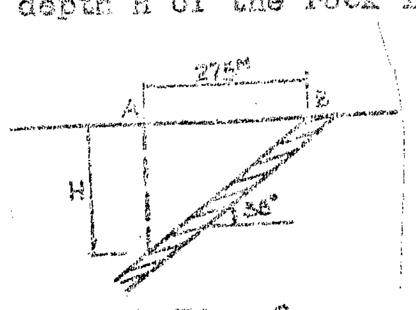


Fig. 8

Solution: Use 90° of the S scale opposite 38° of the ∅ scale, and opposite 275 of the n scale read the number on

the T scale. $H = 275 m. \quad tg 38^{\circ} = 214.9 m.$

Ex. 7: As in Fig. 9, the given ground inclined angle is 19° (perpendicular extending direction of rock layer), the outcome width of the ground rock layer is 130 meters, and its bearing angle is 30°. What are the real thickness h and false thickness H of the rock layer?

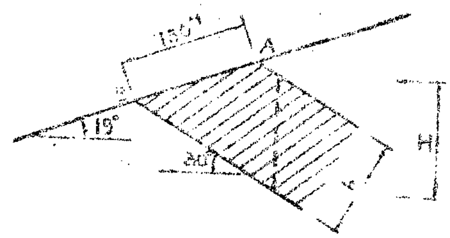


Fig. 9

Solution: Find the h value as in Ex. 3, which equals 98.15 meters. Find the H value by setting 71° of the S scale opposite 30° of the Ø scale and opposite 130 of the n scale to read the number on the T scale.

$h = 130 m \sin(30^{\circ}+19^{\circ}) = 130 m \sin 49^{\circ} = 98.15 m$

$H = 130 m (\sin 19^{\circ} + \cos 19^{\circ} tg 30^{\circ}) = 130 m \sin 19^{\circ} + 130 m \sin 71^{\circ} tg 30^{\circ} = 113.3 m.$

The above examples commonly occured in our computation; other examples which are not mentioned here can be calculated in the same manner by the readers with the exception of a few special cases. The formulas used in this article are adopted from "Geological Drawings", "Structural Geology and Field Geology", volume 1 and 2, and "Geologic Structures", etc.

IV. Merits of the Geological Computation Disc.

1. In comparison with general graphs and tables, its efficiency is 4-6 times higher.

2. The results are accurate and reliable.

3. It is applicable to oblique false bearing angle on the section under various different vertical and horizontal scales.

4. It can replace various geological computation tables.

5. It reduces the stress of using our minds (to use tables, it is generally required to interpolate certain numbers which is not only time consuming but also troublesome; moreover, it leads easily to mistakes).

6. It is easy to carry and convenient to apply.

7. It is easy for scaling gradation and construction and is also accurate.

In constructing the computation disc and preparing the article, I received many suggestions and contributions from Ko Fu-chao (5514 4395 3513), P'eng Cheng-p'ing (1756 2973 1627), Huang Shan-hsien (7806 0810 0341) and others.

After completion of the model construction, it was sent to the Russian geologist "Pi-te-lo-fu" for comments. With his suggestions and encouragement, I rewrote this article with some improvements. The writer wishes to express his sincere appreciation to those who contributed to this article.

10,507
CSO: 1599-S/c

-END-